LXX.—*On the Colours of the Sea Anemone*, Tealia crassicornis. By RICHARD ELMHIRST and JOHN SMITH SHARPE.

(From the Marine Biological Station, Millport.)

IN a previous paper (1920) we detailed an attempt to interpret something of the colour-variations of *Actinia equina*, and showed that the lipochrome pigments of that species act as " optical sensitisers producing active oxygen for the use of the animal through the medium of the respiratory pigment." This study has been extended to the species of *Tealia crassicornis* with similar results so far as the littoral forms are concerned.

Part I.—ENVIRONMENTAL. By RICHARD ELMHIRST.

Habitat, etc.—*Tealia crassicornis* is a well-known Anemone " distributed everywhere on the British coasts " (Gosse, p. 216) from the *Fucus serratus* level of the intertidal zone to moderate depths. Considerable changes are noticeable in the general characters and habits of the species as it is followed from littoral to benthic habitat. Taking (1) proportions, (2) texture of the skin, (3) occurrence of the wart-like suckers on the column, (4) habit of dressing in shell-débris etc., (5) pigmentation, and (6) exposure sought at various depths in tabular form :—

	LITTORAL.	SUB-LITTORAL, including caves and large rock-pools.	DEEP-WATER.
1.	Small and low, up to 3″ broad × 1″ high.	Larger, height about equal to width.	Large, 6″ or more, usually higher than broad.
2.	" Firm and even cartilaginous " (*Gosse*).	Less firm.	Soft.
3.	Column thickly covered with wart-like suckers.	Less warty.	Warts absent, or of irregular occurrence.
4.	Generally dressed in fragments of shell etc., closed during ebb, often half-buried in substratum.	Dressing not usual, always expanded, except when feeding.	....
5.	Heavy pigmentation of green, red, and brown; opaque.	Brighter reds, less dull green and brown.	Red and paler; pellucid.
6.	In shelter under stones and in crevices, often several together.	Sides of caves, exposed on boulders, often numerous.	Single, on stones or large shells.

We find that as we go from the shore to deep-water:

(1) The firm tough skin of the littoral forms disappears.
(2) Individuals become larger.
(3) The wart-like suckers disappear.
(4) The habit of dressing correlated with 3 also disappears.
(5) Intensity of pigmentation and tendency to close up decrease.
(6) Exposure to tidal currents is sought rather than shelter in crevices.

Details confirming these conclusions may be found in the pages of Gosse (1860), Newbigin (1901), and various faunistic works too numerous to list. Examination of specimens from various localities and depths confirms Gosse's view that the shore *Tealia* (species *coriacea,* Cuvier) and the deep-water *Tealia* (species *crassicornis*, Müller) are forms of one variable species, and indicates that intermediate gradations occur in habitats of intermediate depth, light-conditions, etc. Some of the Clyde *Tealiæ* are very near *T. tuberculata* (Cocks), which Gosse (p. 217) suggests is a synonym of *crassicornis,* but Dr. Cunningham (1890) inclined to regard them as separate. More recently Prof. Gemmill (1920) has studied the development of these shore and deep-water forms, and writes (p. 453):—"On general grounds I would have judged that the shore and the submerged forms were varieties of the same species had my account (see below) of the development of the mesenteries in the latter agreed with that of Faurot for the former." Later, he adds, "Material is being collected for a revisal of his work on this point"—viz., the order of occurrence of the primary mesenteries. I think it is well to add here that Faurot had no opportunity of examining very young specimens in which the primary mesenteries and tentacles were being formed.

Colour Significance.—The colour-schemes of littoral *Tealiæ* are innumerable and extraordinarily variable, but the general prevalence, particularly on the column, of heavy red, green, and brown lipochromes suggests that the pigmentation has a physiological function as in *Actinia.* Spectroscopically and in certain chemical characters these red, green, and brown pigments are identical with the similar pigments in *Actinia* (McMunn, 1885), and we presume, therefore, have similar functions. In the case of *Actinia,* Mr. Sharpe showed "experimentally by Wager's method that these red and brown substances produce photo-chemical action with the release of active oxygen" (1920, p. 53), but in the case of *Tealia* he has been unable to get a definite result, owing to the vast quantities of mucus which pour from the tissues of *Tealia* when handled for the purpose. However, we still hope for a definite result, when a suitable modification of method and apparatus has been devised.

Besides any physiological function of the body-pigments, the general colour-schemes of contrasting patches of colour are to be regarded as protective in virtue of their "obliterative" value. Further, the habit of dressing seems to have a double protective function—firstly, as concealment and, secondly, as a check against dessication during ebb-tide. Similarly, the uniform brownish-olive tint of certain shore *Tealiæ* serves well for concealment, but it is impossible to detail every type of colour-pattern adopted by this protean species.

The varied colour-schemes of the tentacles and disc, together with the indefinite outline produced by the markings and disposition of the expanded tentacles, would seem to be a camouflage of still greater "aggressive" value. Confirmation of this is obtained by the following experiment:—Paint an expanded *Tealia* on a cardboard disc, shading in the natural background between the tentacles; cut out the coloured part of the disc and fix it on the top of the spindle of a hand-driven centrifuge, and spin comparatively slowly, when it will usually be found that the colours of the painting complement each other, giving the appearance of a white or faintly bluish disc. Sometimes when the primary disc-bands are strongly marked they form, when being spun, a reddish ring. The conclusion drawn from this experiment is that the camouflage-value of the general colour-scheme of the oral surface is very great, and is such that animals of imperfect powers of vision (*e. g.,* Amphipods) would fail to detect, visually, any danger from the presence of an anemone and swim straight into its clutches, which is exactly what normally happens. In the case of *Tealiæ* with very strong red markings on the disc, such markings might be "warning-coloration," and any creature seeing them and reacting would probably go straight into the outspread tentacles, in which case the final effect is to be regarded as, primarily, aggressive and, possibly, secondarily, warning (*cf.* Fleure and Walton, 1907, p. 218).

The facts that *Tealiæ* frequent sheltered crevices and expose the oral surface chiefly during flood-tide, when even the few feet of sea-water covering them cut off some light, tend to enhance the camouflage-value of the oral colour-schemes. Innumerable as the colour-patterns of the oral surface of this species are, they may be grouped more or les as follows :—

Type 1. Colours complementary.
Type 2. Red of the primary disc-bands outstanding.
Type 3. Uniform sombre tint.
Type 4. Disc as any of the above associated with white tentacles.

Tealiæ in captivity are usually expanded at night, and I can confirm the observations of Fleure and Walton that they react to strong light by closing, which surely indicates that the pigmentation of the oral surface is adapted for use in weak light, whilst the denser pigmentation of the body-wall serves in strong light.

The lighter lipochrome pigmentation, brighter colours, and almost continual exposure of the oral surface of cave-dwelling and sublittoral specimens living in less brilliant light-conditions illustrates the reduction of pigment in reduced light, which is still further confirmed by the delicate colouring, absence of heavy lipochromes, and pellucid nature of specimens from depths of 30 fms. and more. The abundance of lipochromes, presumably with the power of producing active oxygen, in shore-forms and the comparative absence of them in specimens from totally submerged habitat, suggests a provision for some respiratory requirement during ebb in the former, which is not necessary to the latter.

Experimental.—When *Tealiæ* are kept in captivity they often lose much of their natural brightness and delicacy of colouring—as has been noted in the case of other species ; in such changes the general tendency is towards the assumption of a uniform sombre tint, such as is found locally in some shore *Tealiæ*. Deep-water *Tealiæ* also when kept in strong light lose brilliance and assume a more or less uniform brick-red shade. To test the relation between pigmentation and daylight, some shore *Tealiæ* were kept in complete darkness for six months in a tank with a good water-supply (well aërated and plankton available as food, more solid food being given fortnightly). At the end of the experiment, the pigmentation of the column, disc, and tentacles was found to have markedly decreased. The disappearance of pigment was most marked in the lower part of the column, and least marked in the tentacles. A rich red deep-water *Tealia* in the same experiment paled noticeably, except in the oral surface, and tended to assume a dull olivaceous shade from below upwards. In *Actinia*, similarly, paling took place ; in *Actinoloba* both orange and white varieties were tried, but showed no change. A reverse result has been obtained in the case of two lightly pigmented *Tealiæ*, of the shore-type, taken in 25 fms. near the Eddystone Light, and kindly sent me by the courtesy of the Director of the Plymouth Laboratory. These specimens were kept in fairly strong daylight, in a good circulation, and in the course of two months showed a marked increase in the intensity of their pigmentation.

In deep water off the Cumbraes very large *Tealiæ* are obtained, some of which show a distinct and beautiful lavender shade in all parts of the animal. This peculiar shade disappears entirely in a few weeks if the specimen possessing it is exposed to experimental tidal conditions (about 5 hours dry in each 24 hours), but remains fairly constant in those possessing it if they are kept continually submerged in well-aërated water. This seems to be a colour-character occurring only in a small percentage of the deep-water specimens.

Summary.

(1) A comparison of various characters, physiological and structural, shows that the shore, deep-water, and intermediate forms of *Tealia* are adaptational varieties of one species, *crassicornis.*

(2) The intricate colour-scheme of the disc and tentacles is a camouflage of great aggressive value, with evidence of warning coloration in some forms. The body-colouring is obliterative.

(3) The occurrence of strong pigmentation (functioning as a light-screen) in littoral forms grading to the pellucid nature of deep-water forms suggests a relation between intensity of light and depth of pigment, which is confirmed by experiment.

(4) The prevalence of red in deep-water forms is dependent on the twilight conditions obtaining in depths of over 30 fms. in this latitude.

(5) Some deep-water *Tealiæ* have a distinctive lavender shade, probably due to a definite pigment.

Part II.—CHEMICAL. By JOHN SMITH SHARPE.

In continuation of the previous work on *Actinia*, the shore and deep-water varieties of *Tealia crassicornis* were investigated. By contrasting these it may be possible to throw further light on the physiological action of the pigments.

The methods used were similar to those recorded in the previous paper (1920).

In the shore variety a very marked amount of hæmoglobin derivative (respiratory pigment) was found, but in the deep-water variety, even in red specimens, a much smaller quantity was demonstrated ; in some cases only the less refrangible band of the reduced alkaline solution was seen. Similarly, the ether-alcohol soluble lipochromes were abundant in shore-forms and scarce in deep-water forms. The positions of their screens were but little different from those found in *Actinia.*

The above-mentioned lavender-tinted deep-water colour-variety gave evidence of what seems to be new pigment, which was extracted in an aqueous-alcohol layer underlying the ether-alcohol extract. It was of a heliotrope-blue colour, and found both in the tentacles and body-wall. This pigment gave two well-marked bands, one in the yellow and one in the blue. The band in the yellow almost corresponded to the less refrangible band of oxyhæmoglobin, but the band in the blue was further to the right than that of the blood-pigment (see figure). Treatment with either acid or alkali, even when very dilute, caused the disappearance of the colour and these bands. Ordinary pigment solvents—chloroform, ether, benzol, etc.—did not take up this blue pigment, which does not seem to agree with any previously recorded. Lankester has described (1873) stentorine a blue pigment from the cortical substance of a Stentoria which gave two strong absorption-bands, one in the red and one in the green, similar to phycocyan, the blue colouring-matter from *Oscillariæ.* The action of dilute acids (acetic, sulphuric, hydrochloric) did not appear to effect any change, but the colour was intensified by the addition of caustic potash, when the band in the red became darker and the more refrangible band disappeared.

M'Kendrick (1881) found that by macerating *Cyanea* in sea-water a sky-blue fluid was obtained, showing two distinct absorption-bands, one in the red and one in the orange. The addition of ammonia produced a copious precipitate soluble in acids, when the colouring-matter again goes into solution.

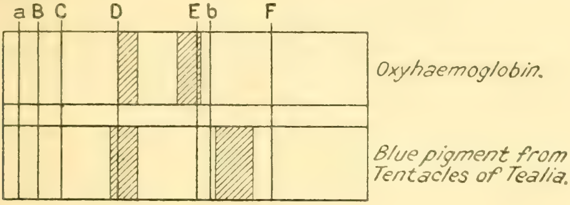
Further, Blanchard (1882) extracted a blue pigment from *Rhizostoma cuvieri* in 90 per cent. alcohol, which gave three bands, in the red, yellow, and green respectively—that in the yellow being almost coincident with the D-line.

Summary.

(1) The shore-forms of *Tealia* are richer in both lipochrome

colouring-matter and hæmoglobin derivative (respiratory pigment) than the deep-water forms. As in *Actinia* the lipochrome-screen presumably acts as an optical sensitiser.

(2) A distinctive new hæmoglobin derivative occurs in a certain lavender-tinted deep-water colour-variety of *Tealia crassicornis*.



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LXXI.—*On some Butterflies from New Guinea and Tenimber*. By the Rev. G. Hulstaert, M.S.C. (Heverlee, Louvain).

Two new races of butterflies are described in the following pages, and a note is added on a form described in a former paper.

The types of the new races are in our collection at Heverlee.

Pieridæ.

Delias argenthona balli, Hulst.

Under this name I described, in the Ann. & Mag. Nat. Hist. (9) xi. p. 180 (1923), as a ♀ form a specimen in our